FIREFIGHTER II MOD A

Fire Behavior

2-2 FIRE BEHAVIOR

2-2.1 Identify the following terms: (*3-3.10*)

- **2-2.1.1** Fire/combustion
- **2-2.1.2** Heat
- **2-2.1.3** Ignition temperature
- **2-2.1.4.** Flammable limits/flammable range
- **2-2.1.5.** Vapor density
- **2-2.1.6.** Solubility

2-2.2 Identify the components of the fire triangle and fire tetrahedron. (*3-3.10*)

2-2.3 Identify the relationship of the concentration of oxygen to combustibility and life safety. (*3-3.1*)

2-2.4 Identify four (4) products of combustion commonly found in structural fires that create a life hazard. *(3-3.1)*

2-2.5 Identify the three (3) methods of heat transfer. (*3-3.9, 3-3.11*)

2-2.6 Identify the Law of Heat Flow.

2-2.7 Identify the three (3) physical states of matter in which fuels are commonly found. (*3-3.9*)

2-2.8 Identify the following conditions and explain their associated hazards and appropriate actions: (*3-3.10*)

- **2-2.8.1** Ignition/Incipient
- **2-2.8.2** Growth/Freeburning
- **2-2.8.3** Rollover/Flameover
- **2-2.8.4** Flashover
- **2-2.8.5** Fully developed
- **2-2.8.6** Decay/Hot smoldering
- **2-2.8.7** Backdraft

2-2.9 Identify the process of thermal layering that occurs in structural fires. (*3-3.11*)

2-2.10 Identify how to avoid disturbing the normal layering of heat.

REFERENCES:

IFSTA, Essentials, 4th ed., Chapter 2
Delmar, Firefighter's Handbook, copyright 2000, Chapter 4
Jones & Bartlett, Fundamentals of Fire Fighter Skills, 1st ed, Chapter 5

2-2 FIRE BEHAVIOR

I. Identify the following fire terms **2-2.1** (*3-3.10*)

A. Fire/Combustion **2-2.1.1**

1. Definitions:

a. Fire: Self-sustaining process of rapid oxidation of a fuel which produces heat and light.
b. Combustion: Self-sustaining chemical reaction yielding energy or products that cause further reactions.
c. These terms are often used interchangeably; most often used is fire.

B. Heat **2-2.1.2**

1. The form of energy that raises temperature.
2. The energy transferred from one body to another when the temperature of the bodies are different.
3. Can be measured by the amount of work it does.

C. Ignition temperature **2-2.1.3**

1. The minimum temperature to which a fuel, in air, must be heated to start self-sustained combustion without a separate ignition source.

D. Flammable Limits/Flammable Range **2-2.1.4**

1. Highest and lowest percentage of a flammable gas or vapor, in air, that will explode or ignite.
2. Concentrations below the Lower Explosive (Flammable) Limit are too “lean” to burn.
3. Concentrations above the Upper Explosive (Flammable) Limit are too “rich” to burn.
4. Flammable (Explosive) Range: The range between the Lower Explosive (Flammable) Limit and the Upper Explosive (Flammable) Limit.

a. The word explosive and flammable are often used interchangeably.

E. Vapor density: **2-2.1.5**

1. Weight of a given volume of pure vapor or gas compared to the weight of an equal volume of dry air at the same temperature and pressure.
2. Vapor density less than one indicates a vapor lighter than air
3. Vapor density greater than one indicates a vapor heavier than air.

F. Solubility **2-2.1.6**

1. Degree to which a solid, liquid, or gas dissolves in a solvent (usually water).

II. Identify the components of the Fire Triangle and the Fire Tetrahedron **2-2.2** (*3-3.1*)

A. Fire Triangle

1. Components

a. Heat
b. Fuel
c. Oxygen

2. Representative of surface combustion (smoldering fire).

B. Fire Tetrahedron

1. Chemical chain reaction is added to the fire triangle.
2. Representative of the flaming mode of combustion.

III. Identify the relationship of the concentration of oxygen to life safety and combustibility. **2-2.3** (*3-3.1*)

A. Concentrations below twenty-one (21) percent have some effect on life safety.

1. At nine (9) percent, an individual becomes unconscious.
2. At six (6) percent, death will occur within a few minutes.

B. In concentrations below eighteen (18) percent, fire begins to decrease.

1. Generally concentrations below fifteen (15) percent will not support combustion.

IV. Identify four (4) products of combustion commonly found in structural fires that create a life hazard. **2-2.4**

A. Heat

1. Responsible for the spread of fire.
2. Cause of burns and other injuries.

B. Smoke

1. Mixture of carbon particles and fire gases.
2. Makeup varies from fuel to fuel; all smoke is considered toxic.
3. The material burning has a direct influence on the amount and color of smoke.

C. Fire Gases

1. Carbon Monoxide (CO)
2. Carbon Dioxide (CO_2)
3. Hydrogen Cyanide
4. Sulfur Dioxide
5. Nitrogen
6. Other gases depending on fuel being burned.

D. Flame (light)

1. More complete the combustion, less luminous the flame
2. Flame absent in smoldering fire

V. Identify the three (3) methods of heat transfer **2-2.5** (*3-3.9, 3-3.11*)

A. Conduction

1. Heat conducted from one body to another either by direct contact or by an intervening heat conducting medium.
2. Depends on type of conductor: metal (good), drywall (poor).
3. Example: Metal plumbing components or electrical conduit.

B. Convection

1. Transfer of heat energy by the movement of air or liquid.
2. Heated gases rise: mushrooming
3. Examples: Fire traveling through elevator shafts, stairways, balloon frame walls.
4. Direct flame contact is actually a form of convection heat transfer.

C. Radiation

1. Transfer by heat waves.
2. Travels through space until it reaches an opaque object.
3. Light colors reflect radiant heat; dark colors absorb radiant heat.
4. Major source of fire spread to exposures. (Important to protect exposures from radiant heat.)

VI. Identify the Law of Heat Flow **2-2.6**

A. Heat flows from a hot substance to a cold substance.
B. A colder substance will absorb heat until temperatures are equal.

VII. Identify the three (3) physical states of matter in which fuels are commonly found. **2-2.7** (*3-3.9*)

A. Solid fuels

1. Have a definite shape and size

a. Surface to mass ratio
b. The more surface areas exposed – the less energy is required for ignition

2. Pyrolysis

a. The chemical decomposition of a substance through the action of heat.

3. The position of the fuel affects the way it burns

a. A solid fuel in a vertical position will allow fire spread more rapidly than the same fuel in a horizontal position

B. Liquid Fuels

1. Fuel gases are generated by a process called vaporization

a. Vaporization: The transformation of a liquid to it's vapor or gaseous state

1. Energy input usually in the form of heat
2. Requires less energy than said fuels

b. With liquids, the surface to volume ratio is important

C. Gaseous fuels:

1. Can be the most dangerous of all fuel types because they are already in the natural state required for ignition

2. Must be mixed with air in the proper proportion to burn; i.e. flammable range

VIII. Identify the following conditions and explain their associated hazards and appropriate actions: **2-2.8** (*3-3.10*)

A. Incipient/Ignition **2-2.8.1**

1. Occurs when the four elements of the fire tetrahedron come together and combustion begins.
2. Can be caused by a spark or flame
3. Can occur when a material reaches its ignition temperature through self-heating
4. Limited to original materials ignited.
5. Small quantity of fire gases being generated.
6. Flame temperature above 1000^0F. yet room temperature is only slightly increased.
7. Easiest to extinguish

B. Growth/Freeburning **2-2.8.2**

1. Fire plume begins to form above the burning fuel
2. Begins to draw air from the surrounding space into the plume
3. Hot gases rise, hit the ceiling and spread until they reach the walls
4. As fire grows, the overall temperature increases
5. Rollover/Flameover **2-2.8.3**

   a. The ignition of combustible gases which have spread throughout the fire area
   b. Differs from flashover in that only combustible gases are burning
   c. One reason why firefighters stay low when entering a burning building
   d. Controlled by extinguishing main body of fire

6. Flame spread: movement of flame away from source of ignition

C. Flashover **2-2.8.4**

1. Transition between the growth stage and fully developed stage of a compartment fire
2. Occurs when flames flash over the entire surface of a room.
3. Occurs as a result of all the materials in the room reaching their ignition temperatures
4. Involves all exposed combustible surfaces in the compartment
5. Temperatures range from 900^0F. – 1200^0F.
6. Survivability unlikely if caught in a flashover

D. Fully developed **2-2.8.5**

1. All combustible materials in the compartment are involved
2. Releasing the maximum amount of heat and producing large amounts of fire gases
3. Hot unburned gases are flowing from the compartment and ignite when they enter a space with abundant air

E. Decay/Hot smoldering fire **2-2.8.6**

1. As fuel is consumed, the rate of heat decreases
2. Amount of fire diminishes and temperature begins to decline
3. Glowing embers can maintain moderately high temperatures

F. Backdraft (smoke explosion) **2-2.8.7**

1. Explosion or rapid burning of heated gases.
2. Occurs when oxygen is introduced into a smoldering fire.
3. Often caused by improper ventilation.
4. Warning signs:

    a. Pressurized smoke exiting small openings
    b. Dense gray-yellow smoke
    c. Confinement and excessive heat
    d. Little or no visible flame
    e. Smoke leaving building in "puffs" (smoke puffing out and then sucking back in)
    f. Smoke stained windows
    g. Muffled sounds
    h. Sudden rapid inward movement of air when an opening is made

5. Situation can be made less dangerous by proper ventilation. Open at highest point involved. Heated smoke and gases will be released, reducing the possibility of an explosion.

IX. Identify the process of thermal layering that occurs in structural fires. **2-2.9** (*3-3.11*)

A. The tendency of gases to form into layers according to temperatures.
B. Sometimes referred to as heat stratification or heat balance.
C. Hottest gases tend to be at the ceiling and cooler gases towards the floor.
D. Thermal layering is critical to firefighting operations.

XI. Identify how to avoid disturbing the normal layering of heat. **2-2.10**

A. Fire streams affect on thermal layering (Heat Balance)

1. Thermal layering can be disrupted if water is applied directly into the layer without proper ventilation.
2. Results in higher temperatures at the floor level and decreased visibility.
3. Firefighters may suffer steam burns if thermal layering is disrupted